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ABSTRACT:

CHG DATE=20001128 STATUS=O> An Al-Mg-Si based aluminum alloy extrusion having large strength, absorbable impact energy and resistance against compressing cracking, wherein the average size of Mg_2Si precipitation in the ?1 0 0? and ?0 1 0? directions of the (1 0 0) plane inside grains is 20 nm or more, the distribution density of the Mg_2Si precipitation in the ?0 0 1? direction of the (1 0 0) plane is 100 or more per mu m<2>, and the size of precipitations on grain boundaries is 1000 nm or less. Alternatively, in the Al-Mg-Si based aluminum alloy extrusion, a tensile strength obtained from a tensile test performed at a strain rate of 1000 per second is from 150 to 400 N/mm<2> (both inclusive).

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(54) Al-Mg-Si based aluminum alloy extrusion

(57) An Al-Mg-Si based aluminum alloy extrusion having large strength, absorbable impact energy and resistance against compressing cracking, wherein the average size of Mg_2Si precipitation in the [1 0 0] and [0 1 0] directions of the (1 0 0) plane inside grains is 20 nm or more, the distribution density of the Mg_2Si precipitation in the [0 0 1] direction of the (1 0 0) plane is 100 or more per μm^2, and the size of precipitations on grain boundaries is 1000 nm or less. Alternatively, in the Al-Mg-Si based aluminum alloy extrusion, a tensile strength obtained from a tensile test performed at a strain rate of 1000 per second is from 150 to 400 N/mm^2 (both inclusive).

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Description

[0001] The present invention relates to an aluminum alloy extrusion, and in particular to an aluminum alloy extrusion which has the following action: when the extrusion receives compressive impact load or compressive static load along its extrusive axis direction, the extrusion absorbs the compressive impact load or compressive static load. Thus, the aluminum alloy extrusion is suitably applied in particular to fabrics for cars, for example, a side member or a bumper stay.

[0002] Recently, attention has been paid to the development of a fuel-efficient car or an electric car from the viewpoint of the protection of the environment. For the attainment thereof, it is essential to make the body of cars light. On the other hand, the weight of cars tends to increase in order to cope with safety standards and improve the performance of the cars. Under such a situation, aluminum alloy extrusions are adopted as, for example, a bumper reinforcement or a frame of cars, and the demand thereof has been expanding for car members for the following reasons. The density of the aluminum alloy extrusions is about one-third of that of iron. The aluminum alloy extrusions have excellent energy absorption. Extruding the aluminum alloy allows various kinds of sectional shapes of extrusions.

[0003] For fabrics for cars, in particular for frames of cars, the following are required in order to absorb impact energy at the time of collision: the property that the aluminum alloy extrusions are deformed into bellows at the time of the collision to absorb the impact energy effectively; high strength; and resistance against compressing cracking for generating no cracks at the time of the deformation into the form of bellows, that is, satisfactory axial compressing property. As materials of frames of cars, such as a side member or bumper stay, for which such axial compressing property is required, for example, Japanese Patent Application Laid-Open No. 9-256096 discloses an extrusion of Al-Mg-Si based alloy, which has relatively high corrosion resistance among high-strength aluminum alloys and is superior in recycling ability to other aluminum alloys.

[0004] As frames of cars, investigations have mainly been made on Al-Mg-Si based aluminum alloy extrusions, which have relatively high strength. Hitherto, however, energy absorption power has generally been evaluated by cutting an extrusion into a given length, compressing the cut piece in its axial direction at a compressive rate of several tens mm/minute to buckle the piece, and obtain an absorbed energy from the resultant load-displacement curve, or by observing whether cracks are generated or not with eyes, as disclosed in, for example, Japanese Patent Application Laid-Open No. 7-118782. Therefore, even if conventional Al-Mg-Si based aluminum alloy extrusions exhibit excellent energy absorption property, it is mere energy absorption property under quasi-static compressive conditions.

[0005] Incidentally, deformation at the time of actual collision is generated at a very great deformation speed. Concerning Al-Mg-Si based alloy extrusions, as well as ordinary materials, extrusions deformed at a high speed are different from extrusions deformed at a low speed in strength. For this reason, in the case that even an extrusion exhibiting satisfactory energy absorption property when it is statically compressed and deformed is compressed and deformed at a high speed, compressing cracks are frequently generated so that its energy absorption property changes.

[0006] Therefore, in order to obtain a material of car frames which is effective against actual collision, it is necessary to obtain an aluminum alloy extrusion which exhibits satisfactory energy absorption property when it is compressed and deformed at a high speed.

[0007] In the case that the strength of Al-Mg-Si based aluminum alloy is raised by addition of alloying components or thermal treatment, the resistance against compressing cracking of the alloy tends to become poorer as the strength of the alloy becomes higher. Thus, it has greatly been desired to develop an aluminum alloy having high strength and satisfactory axial compressing property, which does not cause compressing cracking.

[0008] Therefore, an object of the present invention is to provide an Al-Mg-Si based aluminum alloy extrusion which causes compressing cracks not to be generated even when deformation in its axial direction occurs at a high speed, as seen in actual collision, and which has large absorbable energy and satisfactory energy absorption property.

[0009] Another object of the present invention is to provide an Al-Mg-Si based aluminum alloy extrusion suitable for fabrics of cars excellent in axial compressing property (high strength and resistance against compressing cracking).

[0010] The inventors made various experiments and researches to develop an Al-Mg-Si based aluminum alloy extrusion excellent in axial compressing property. As a result, the inventors have found that excellent axial compressing property can be obtained if the followings are within specific ranges: the size and the distribution of Mg_2Si precipitation in specified directions of the (1 0 0) plane inside grains of an alloy; and the size of precipitations such as Mg_2Si on grain boundaries. The present invention has been made on basis of these findings.

[0011] Thus, a first aspect of the present invention is an Al-Mg-Si based aluminum alloy extrusion, wherein the average size of Mg_2Si precipitation in the [1 0 0] and [0 1 0] directions of the (1 0 0) plane inside grains is 20 nm or more, the distribution density of the Mg_2Si precipitation in the [0 0 1] direction of the (1 0 0) plane is 100 or more per μm^2, and the size of precipitations on grain boundaries is 1000 nm or less. This Al-Mg-Si based aluminum alloy extrusion has satisfactory axial compressing property. Therefore, the extrusion is suitable for use as a crushable member (i.e., a member having such an action that when it receives compressive impact load or compressive static load in its axial direction, it crushes in the axial direction to absorb the impact load or the static load).

[0012] Furthermore, during various experiments and researches for developing an Al-Mg-Si based aluminum alloy extrusion excellent in energy absorption property when it is compressed and deformed at a high speed, the inventors have found that the tensile strength used in the case of performing a tensile test at a high speed is closely related to energy absorption property when the extrusion is compressed and deformed at a high speed.

[0013] Thus, a second aspect of the present invention is an Al-Mg-Si based aluminum alloy extrusion excellent in impact energy absorption property, wherein a tensile strength obtained from a tensile test performed at a strain rate of 1000 per second is from 150 to 400 N/mm^2 (both inclusive), preferably from 200 to 370 N/mm^2 (both inclusive). The Al-Mg-Si based aluminum alloy extrusion satisfying these requirements can be deformed in bellows when it is compressed and deformed at a high speed, to exhibit excellent impact energy absorption property.

FIG. 1 is a cross section of an hollow extrusion produced in Examples.

FIG. 2 is a view for explaining the method of a compressing test performed in the Examples.

FIG. 3 is a view for explaining a high-speed compressing test performed in the Examples.

[0014] In the aluminum alloy extrusion according to the first aspect of the present invention, reasons for limiting the ranges of the size and distribution density of the precipitation inside grains and the size of the grain boundary precipitations.

[Size of the precipitation inside the grains]

[0015] The Mg_2Si precipitation inside the grains precipitates in a rod form in the ⟨1 0 0⟩ direction at the time of artificial aging treatment, so as to disturb dislocation movement. This causes the strength of the extrusion to be raised. If the average size of the precipitation in the [1 0 0] and [0 1 0] directions of the (1 0 0) plane inside the grains is less than 20 nm, the precipitated grains are shorn by the dislocation at the time of the compression and deformation of the extrusion. In this case, subsequent dislocation moves very easily on the slip plane (the (1 1 1)plane), so that straight and coarse slip band texture is generated. For this reason, stress concentrates on the grain boundaries so that the grain boundaries are ruptured. Thus, such an extrusion has poor resistance against compressing cracking. It is more preferable that the average size of the precipitation is 30 nm or more. However, if the size of the precipitation is too large, the strength drops. Thus, it is desirable that the average size thereof is not over 1000 nm.

[Distribution density]

[0016] The distribution density of the Mg_2Si precipitation, as well as the size of the precipitation, has an influence on the strength of the extrusion. In the case that the distribution density of the precipitation in the [0 0 1] direction of the (1 0 0) plane inside the grains is less than 100 per µm^2, the extrusion has low strength and less absorbed energy at the time of compression and deformation of the extrusion. Therefore, the distribution density is set up to 100 per µm^2 or more. In order to obtain higher strength, the distribution density is preferably 400 per µm^2 or more. If the distribution density becomes too large, compressing cracking is liable to occur. Thus, the distribution density is preferably 2000 per µm^2 or more.

[0017] The size and the distribution density of the Mg_2Si precipitation are measured by a measuring method that will be described later.

[Grain boundary precipitations]

[0018] The Mg_2Si precipitation, a simple substance Si and the like on the grain boundaries are produced in the cooling after the extruding or the solution treatment, and have an influence on the rupture form of the grain boundaries. If the size of the grain boundary precipitations is over 1000 nm, the precipitations become starting points of cracks so that the grain boundaries rupture. This makes the resistance against compressing cracking of the extrusion poor. The size of the precipitations is preferably 500 nm or less.

[0019] In the Al-Mg-Si based aluminum alloy extrusion according to the first aspect of the present invention, its crystal texture is preferably a fiber texture. The fiber texture is a hot-worked texture, as seen in extrusions, wherein grains are stretched in its extrusive direction.

[0020] The strain in a material, when it is deformed, is induced by the movement of dislocation. This dislocation disappears at a portion where the arrangement of metal crystal is irregular, such as a grain boundary. Therefore, lattice gaps accumulate in such a portion so that strains concentrate on the portion. Thus, the distribution of the dislocation (that is, the distribution of the strains) is likely to be more uniform in the material as the size of its grains is smaller. In

order to suppress generation of cracks at the time of compressing, it is necessary to make deformation-strains uniform in the material. By suppressing recrystallization to keep the fiber texture, that is, the grain boundaries in a fine state, the deformation-strains can be distributed uniformly in the material to improve strength and resistance against compressing cracking and enlarge absorbable energy.

[0021] The Al-Mg-Si based aluminum alloy according to the first aspect of the present invention is a precipitation hardening alloy made mainly of Mg and Si. A preferable composition thereof is a composition comprising Mg: 0.2-1.6%(% represents % by weight (wt) throughout the present specification) and Si: 0.2-1.8%, and optionally Cu: 1.0% or less, Mn: 0.05-0.5%, and one or more selected from the following: Ti: 0.01-0.1%, Cr: 0.01-0.2% and Zr: 0.01-0.2%. The balance thereof is Al and impurities. If the amount of Fe as an impurity is 0.7% or less and each amount and the total amount of other impurities are 0.05% or less and 0.15%, respectively, the properties of the present alloy are not adversely effected.

[0022] Reasons why the amounts of the respective components are limited are as follows.

[Mg and Si]

[0023] Mg and Si are elements for forming the Mg_2Si precipitation and strengthen the alloy. In the case of Mg: less than 0.2% or Si: less than 0.2%, it is impossible to obtain strength necessary for a fabric or an energy absorbable member to which an impact load or static load is applied to its axial direction. On the other hand, in the case of Mg: over 1.6% or Si: over 1.8%, the deforming ability of the extrusion drops, so that secondary working thereof becomes difficult. Moreover, the deformation in the extrusive axis direction easily causes compressing cracking. Therefore, the composition of the alloy is set to comprise Mg: 0.2-1.6% and Si: 0.2-1.8%, and especially preferable Mg: 0.4-0.8% and Si: 0.7-1.1%.

[Cu]

[0024] Cu has an action of improving the matrix strength of the alloy in accordance with the added amount thereof. Thus, Cu may be appropriately added. In order to obtain this action, the added amount of cu is preferably 0.1% or more. However, if the added amount thereof is over 1%, the alloy has reduced corrosion resistance, resistance against stress corrosion cracking and weldability. Furthermore, compressing cracking is liable to occur by the deformation in the extrusive axial direction. Therefore, if Cu is added, the upper limit of the amount thereof is 1.0%. In the case, the amount thereof is especially preferably from 0.15-0.7%.

[Mn]

[0025] Mn has effect of suppressing recrystallization of the alloy texture to make the texture fine. Thus, Mn may be appropriately added. On the basis of this property, Mn has an function for stabilizing the fiber texture of the extrusion. These effects can be exhibited by the addition of 0.05% or more of Mn. The addition of more than 0.5% of Mn causes diffusion of Mg, when the alloy is thermally heated, to be suppressed so as to deteriorate thermal treating ability and further causes coarse compounds to be generated so as to deteriorate resistance against compressing cracking. For this reason, the added amount of Mn is preferably from 0.05-0.5%.

[Ti, Cr and Zr]

[0026] Ti is generated as nuclei at the time of melting and casting of the alloy, and has an action of making the texture of the cast product fine. Thus, Ti may be appropriately added. This effect becomes remarkable by the addition of 0.005% or more of Ti. If the added amount thereof is over 0.1%, coarse compounds are generated to cause the deterioration in resistance against compressing cracking. Thus, the added amount thereof is preferably from 0.01 to 0.1%.

[0027] Cr has a pinning effect in the grain boundaries of the alloy to stabilize the fiber texture of the extrusion. Thus, Cr may be appropriately added. This effect can be exhibited by the addition of 0.01% or more of Cr. However, if the amount thereof is over 0.2%, the initial pressure for extruding working is remarkably raised. This is not practicable. Thus, the added amount thereof is preferably from 0.01 to 0.2%.

[0028] Zr also has a pinning effect in the grain boundaries of the alloy to stabilize the fiber texture of the extrusion. Thus, Zr may be appropriately added. This effect can be exhibited by the addition of 0.01% or more of Zr. However, if the amount thereof is over 0.2%, the effect for stabilizing the fiber texture is not improved any more. Thus, the added amount thereof is preferably from 0.01 to 0.2%.

[0029] In order to produce the extrusion of the present invention by use of the above-mentioned Al-Mg-Si based aluminum alloy, the alloy is melted and cast in the usual manner to prepare an ingot. The ingot is then subjected to a homogenizing treatment. The resultant is hot-extruded into a desired sectional shape, and immediately thereafter, the extruding is quenched (press-quenched). Alternatively, the resultant is hot-extruded and then is subjected to a solution

and quenching treatment. The hot-extruding/press-quenching is a treatment of extruding an ingot and simultaneously using extruding-temperature to conduct a solution treatment. It is important that the extruding temperature is set up to temperature for the solution treatment. In order to obtain the fiber texture at this time, the extruding-temperature is set to an appropriate temperature in the manner that the fiber texture after the extruding is not recrystallized into coarse recrystallized grains. In the case of the hot-extruding followed by the solution and quenching treatment, the fiber texture is not recrystallized into coarse recrystallized grains after the hot-extruding or during the solution treatment. In order to prevent the boundary grain precipitation from getting coarse and keep its size within the above-mentioned range, it is necessary to quench the alloy immediately after the solution treatment(after the extruding in the former case). Subsequently, the alloy is subjected to an aging treatment to precipitate Mg_2Si in the grains.

[0030] The more specifically described producing conditions for obtaining the extrusion according to the first aspect of the present invention is as follows:

homogenizing temperature: 450 °C - 550 °C ;
homogenizing time: 2 hours - 8 hours;
extruding temperature: 470 °C - 530 °C ;
aging temperature: 160 °C - 230 °C ;
aging time: 1 hour - 8 hours.

[0031] In the case of using the Al-Mg-Si based aluminum alloy extrusion according to the first aspect of the present invention particularly as fabrics for cars such as a side member or a bumper stay, the extension after the aging treatment preferably has a tensile strength of 200 N/mm^2 or more and a proof stress of 150 N/mm^2 or more to obtain high absorbable energy.

[0032] According to the first aspect of the present invention, it is possible to obtain an aluminum alloy extrusion which is very excellent in axial compressing property and is suitable for fabrics for cars such as a side member by restricting the size of the precipitation inside the grains and the distribution density and the size of the grain boundary precipitations.

[0033] The following will describe the aluminum alloy extrusion according to the second aspect of the present invention.

[0034] In the second aspect of the present invention, as a tensile rate at a high-speed tensile test, a strain rate of 1000 per second is selected. The tensile strength obtained in the tensile test performed under this condition is decided as an index for representing energy absorption property at the time of high-speed compression and deformation of any alloy extrusion. The tensile test performed under a strain rate of 1000 per second corresponds to a strain rate of a car material deformed when a car collides at about 30-40 km/h. The behavior of a car when it collides at 30-40 km/h is similar to that of the car when it collides at any speed more than 30-40 km/h.

[0035] If the tensile strength at a strain rate of 1000 per second is less than 150 N/mm^2, the alloy extrusion has only small absorbable energy at the time of compressing and deforming the alloy extrusion at a high speed and the alloy extrusion does not satisfy strength necessary for fabrics for cars. On the other hand, if the tensile strength at a strain rate of 1000 per second is over 400 N/mm^2, compressing cracking occurs at the time of compressing and deforming the alloy extrusion at a high speed. Thus, the alloy extrusion is unsuitable for energy absorbable members.

[0036] The Al-Mg-Si based aluminum alloy according to the second aspect of the present invention is a precipitation hardening alloy. A preferable composition thereof is a composition comprising Mg: 0.2-1.6% and Si: 0.2-1.8%, and optionally (1) Cu: 1.0% or less, (2) Ti: 0.005-0.2%, and (3) one or more selected from the following: Mn: 0.05-0.5% or less, Cr: 0.01-0.2% and Zr: 0.01-0.2%. Any one or a combination of the (1)-(3) may be contained. The balance thereof is Al and impurities. An especially preferable composition is a composition comprising Mg: 0.35-1.1%, Si: 0.5-1.3%, Cu: 0.15-0.7%, Ti: 0.005-0.2%, Zr: 0.01-0.2%, and one or two of Mn: 0.05-0.5% and Cr: 0.05-0.15%. If the amount of Fe as an impurity is 0.7% or less and each amount and the total amount of other impurities are 0.05% or less and 0.15% or less, respectively, the properties of the present alloy are not adversely effected.

[0037] Reasons why the amounts of the respective components are limited are essentially the same as in the first aspect of the present invention.

[0038] In the same way as in the first aspect of the present invention, it is preferable that the crystal texture is a fiber texture.

[0039] If the Zr is added in an amount more than the given amount, resistance against compressing cracking of the alloy extrusion subjected to over aging treatment is greatly improved. Zr causes a less drop in press-quenching ability than Mn and Cr. Since Cr causes deterioration in the surface performance of the extrusion, it is preferable that Zr is first added and subsequently Mn and/or Cr are/is added. To exhibit the effect of Zr sufficiently in this case, the composition of the extrusion is set up to comprise Zr: 0.06-0.2% and further Mn: 0.05-0.5% and Cr: 0.05-0.15%.

[0040] The producing conditions for obtaining the extrusion according to the second aspect of the present invention is as follows:

homogenizing temperature: 450 °C - 550 °C ;
homogenizing time: 2 hours - 8 hours;
extruding temperature: 470 °C - 530 °C ;
aging temperature: 160 °C - 230 °C ;
aging time: 1 hour - 8 hours.

[0041] According to the second aspect of the present invention, it is possible to obtain an aluminum alloy extrusion which has excellent energy absorption property, when being deformed at a high speed, and is suitable for a raw material of fabrics for cars such as a side member.

Examples

[0042] The present invention will be described with comparison of Examples according to the present invention with Comparative Examples.

Example 1

[0043] In the usual manner, there were obtained ingots (diameter: 155 mm) of several kinds of aluminum alloys comprising Mg and Si as mainly-added elements. Next, these ingots were subjected to a homogenizing treatment at 550 °C for 8 hours. Thereafter, the respective billets were extruded at an extruding temperature of 500 °C and an extruding speed of 5 m/min. Immediately thereafter, the resultant extrusions were cooled with water (average cooling rate: about 12000 °C/min.) or air (average cooling rate: about 190 °C/min.) to obtain angular pipes having a long side of 60 mm, a short side of 40 mm and a thickness of 2 mm. Their cross section is shown in FIG. 1. Next, these angular pipes were subjected to an artificial aging treatment to obtain samples. Tables 1 and 2 show alloy compositions and treatment conditions of the respective samples.

Table 1

Chemical Components (% by weight)									
No.	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr
1	0.40	0.15	tr.	tr.	0.70	tr.	tr.	0.02	tr.
2	0.55	0.15	0.10	0.10	0.70	0.05	tr.	0.02	0.05
3	0.90	0.25	0.50	0.35	0.60	tr.	tr.	0.02	0.15
4	0.90	0.25	0.50	0.35	0.60	tr.	tr.	0.02	0.15
5	0.90	0.25	0.50	0.35	0.60	tr.	tr.	0.02	0.15
6	0.40	0.15	tr.	tr.	0.70	tr.	tr.	0.02	tr.
7	0.55	0.15	0.10	0.10	0.70	0.05	tr.	0.02	0.05
(tr:trace)									

Table 2

Treatment Conditions			
No.	Quenching manner	Aging temperature	Aging hour
1	Cooling with water	190 °C	3 hours
2	Cooling with water	190 °C	3 hours
3	Cooling with water	190 °C	3 hours
4	Cooling with water	210 °C	3 hours
5	Cooling with water	160 °C	6 hours

Table 2 (continued)

Treatment Conditions			
No.	Quenching manner	Aging temperature	Aging hour
6	Cooling with water	230 °C	3 hours
7	Cooling with air	190 °C	3 hours

[0044] Test pieces according to JIS No. 5 were taken out from these samples. These test pieces were used to measure their tensile strength σ_B, proof stress $\sigma_{0.2}$ and rupture elongation δ according to a metallic material tensile test defined in JIS Z 2241.

[0045] The respective samples (length: 200 mm) were subjected to compressing tests. FIG. 2 illustrates a method of the compressing tests. A load was applied to a sample 1 in its axial direction by means of a universal test machine 2. Based on the test results, a displacement-load diagram was prepared. From this diagram, absorbable energy up to a displacement of 100 mm was obtained. Cracking resistance was evaluated based on cracks generated in the compressing test. The samples in which no cracking occurred are represented by ○ . The samples in which cracking occurred are represented by X.

[0046] Test pieces were taken out from the samples and then a transmission electron microscope was used to observe the (1 0 0) plane thereof at 200,000 magnifications. Among respective grains of Mg_2Si precipitation precipitated in the [1 0 0] and [0 1 0] directions, only precipitated grains having a length in the [1 0 0] or [0 1 0] direction of 5 nm or more were measured about their length. The same (1 0 0) plane was observed to examine the number of Mg_2Si grains which were precipitated in the [1 0 0] direction and had a diameter of 1 nm or more. Thus, the distribution density thereof was obtained. Each of the measurements was performed concerning 4 visual fields of each of the samples (total observed area: 0.16 μm^2), and then the average thereof was obtained. The same samples were used to obtain the maximum size of precipitations such as Mg_2Si or a simple substance Si on grain boundaries.

[0047] The thus obtained results are shown in Table 3. These samples were comprehensively evaluated about aptitude as a raw material of fabrics for cars, such as a side bumper. The results are also shown in Table 3. The samples suitable for fabrics for cars, such as a side bumper, are represented by ○ . The samples unsuitable for fabrics for cars, such as a side bumper, are represented by X.

Table 3

Test Results

Samples		Matrix Mg_2Si		Size of grain boundary precipitations (nm)	Tensile properties			Compressing properties		Overall evaluation
		Average size (nm)	Distribution density (number per μm^2)		σ_B (N/mm^2)	$\sigma_{0.2}$ (N/mm^2)	δ (%)	Absorbable energy (J)	Cracking resistance	
Ex.	1	50.7	150	38.7	208	183	10.1	2350	○	○
	2	38.0	544	54.6	274	255	11.8	3240	○	○
	3	33.9	831	39.2	350	316	15.6	4360	○	○
	4	65.0	594	27.4	310	271	15.2	4170	○	○
Comp.	1	13.1 *	2075	16.8	363	291	19.6	4530	×	×
	2	85.3	96 *	63.5	176	143	10.4	1840	○	×
	3	26.2	919	1828 *	268	244	10.2	2410	×	×

Ex.: Examples

Comp.: Comparative Examples

*: Out of the scope of the first aspect of the present invention

[0048] As is evident from Table 3, all of samples Nos. 1-4 according to the present invention had axial compressing property (absorbable energy and cracking resistance). On the other hand, all of samples Nos. 5-7 according to Com-

parative Examples had unsatisfactory axial compressing property.

Example 2

[0049] Aluminum alloy billets having the compositions shown in Table 4 and having a diameter of 155 mm were first produced by melting and casting in a usual way.

Table 4

Chemical compositions (% by weight)									
No.	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr
1	0.90	0.30	0.50	0.35	0.65	tr.	tr.	0.02	0.13
2	0.55	0.20	0.10	0.10	0.70	0.05	tr.	0.02	0.05
3	0.40	0.15	tr.	tr.	0.60	tr.	tr.	0.02	tr.
4	0.40	0.15	tr.	tr.	0.60	tr.	tr.	0.02	tr.
5	0.59	0.23	0.20	0.15	0.51	tr.	tr.	0.02	0.11
6	0.20	0.20	tr.	tr.	0.65	tr.	tr.	0.02	tr.
7	1.20	0.30	0.90	0.36	1.00	0.15	tr.	0.02	0.13
(tr.: trace)									

[0050] Next, these ingots were subjected to a homogenizing treatment at 550 °C for 4 hours. Thereafter, the respective billets were extruded at an extruding temperature of 500 °C and an extruding rate of 5 m/minute, and immediately thereafter the extrusions were cooled with water (at an average cooling rate of 12000 °C /minute) or cooled with air (at an average cooling rate of 190 °C/minute) to produce angular pipes having a 70 × 50 mm section and a thickness of 2 mm. Their cross section is shown in FIG. 1. These angular pipes were subjected to an artificial aging treatment to prepare samples. Treating conditions are shown in Table 5.

Table 5

Treatment conditions			
No.	Quenching manner	Aging temperature	Aging hour
1	Cooling with water	190 °C	6 hours
2	Cooling with air	190 °C	3 hours
3	Cooling with air	190 °C	3 hours
4	Cooling with water	190 °C	3 hours
5	Cooling with air	190 °C	3 hours
6	Cooling with water	170 °C	8 hours
7	Cooling with water	190 °C	3 hours

[0051] Test pieces based on JIS No. 5 test pieces disclosed in Japanese Patent Application Laid-Open No. 10-318894 were taken out in their longitudinal direction from these samples, and then they were subjected to a tensile test at a strain rate of 1000 per second in which the measuring method disclosed in this publication was used. The results are shown in Table 6.

[0052] The respective samples (length: 200 mm) were subjected to a compressing test at a high speed. FIG. 3 shows the compressing test. A load (200kgf) was applied to the samples in their axial direction by a dropping weight 3. The load was measured with a load cell 4. The speed of the dropping weight was about 50 km/hour. On the basis of the test results, displacement-load diagrams were prepared. From the displacement-load diagrams, absorbable energies were measured in the range up to a displacement of 100 mm. Samples having an absorbable energy of 2000 J or more

are represented by ○ , and samples having an absorbable energy of less than 2000 J are represented by X. At the same time, resistance against compressing cracking of the compressing samples was judged with naked eyes. Samples in which no cracking occurred are represented by ○ , and samples in which cracking occurred are represented by X. The results are also shown in Table 6.

[0053] Furthermore, from these results the samples were evaluated about aptitude for a raw material of car parts such as a side bumper. The results are also shown in Table 6. Samples which were excellent in both of the absorbable energy and resistance against compressing cracking are represented by ○ , and samples which were poor in either of them are represented by X.

Table 6

Test results					
	No.	Tensile strength at a strain rate of 1000 per second (N/mm^2)	Absorbable energy (J)	Cracking resistance	Aptitude
Example	1	330	3100	○	○
	2	275	2950	○	○
	3	205	2450	○	○
	4	250	2800	○	○
	5	266	2930	○	○
Comparative Example	6	120	1050	○	X
	7	440	3500	X	X

[0054] Samples Nos. 1-5 satisfying the requirements according to the second aspect of the present invention were deformed into the form of bellows, and had good absorbable energy and resistance against compressing cracking. They were suitable for a material of car parts such as a side member. Among the samples, sample No. 1 was a sample subjected to an over aging treatment, and had especially high strength and absorbable energy, i.e., especially good resistance against compressing cracking. On the other hand, samples No. 6 and No. 7 were poor in the absorbable energy and the resistance against compressing cracking, respectively, and thus were unsuitable for a raw material of car parts.

Claims

1. An Al-Mg-Si based aluminum alloy extrusion, wherein the average size of Mg_2Si precipitation in the [1 0 0] and [0 1 0] directions of the (1 0 0) plane inside grains is 20 nm or more, the distribution density of the Mg_2Si precipitation in the [0 0 1] direction of the (1 0 0) plane is 100 or more per μm^2, and the size of precipitations on grain boundaries is 1000 nm or less.

2. The Al-Mg-Si based aluminum alloy extrusion according to claim 1, which comprises an Al-Mg-Si based aluminum alloy comprising Mg: 0.2-1.6% wt and Si: 0.2-1.88% wt.

3. The Al-Mg-Si based aluminum alloy extrusion according to claim 2, which comprises an Al-Mg-Si based aluminum alloy comprising Cu: 1.0% wt or less.

4. The Al-Mg-Si based aluminum alloy extrusion according to claim 2 or 3 which comprises an Al-Mg-Si based aluminum alloy comprising Mn: 0.05-0.5% wt or less.

5. The Al-Mg-Si based aluminum alloy extrusion according to any one of claims 2 to 4,
which comprises an Al-Mg-Si based aluminum alloy comprising one or more selected from the following:

Ti: 0.01-0.1% wt or less, Cr: 0.01-0.2% wt and Zr: 0.01-0.2% wt.

6. The Al-Mg-Si based aluminum alloy extrusion according to any one of claims 1 to 5,

wherein the texture of the crystal is a fiber texture.

7. The Al-Mg-Si based aluminum alloy extrusion according to any one of claims 1 to 6, which has a tensile strength of 200 N/mm^2 or more, and a proof stress of 150 N/mm^2 or more.

8. An Al-Mg-Si based aluminum alloy extrusion excellent in impact energy absorption property, wherein a tensile strength obtained from a tensile test performed at a strain rate of 1000 per second is from 150 to 400 N/mm^2 (both inclusive).

9. The Al-Mg-Si based aluminum alloy extrusion according to claim 8, which comprises an Al-Mg-Si based aluminum alloy comprising Mg: 0.2-1.6% wt and Si: 0.2-1.8% wt.

10. The Al-Mg-Si based aluminum alloy extrusion according to claim 9, which comprises Mg: 0.35-1.1% wt, Si: 0.5-1.3% wt, Cu: 0.15-0.7% wt, Ti: 0.005-0.2% wt and Zr: 0.01-0.2%wt, and further comprises one or two selected from the following: Mn: 0.05-0.5%wt and Cr: 0.05-0.15% wt, the balance being Al and impurities.

11. A fabric for a car, which comprises an extrusion of the Al-Mg-Si based aluminum alloy extrusion according to any one of claims 1 to 10.

FIG.1

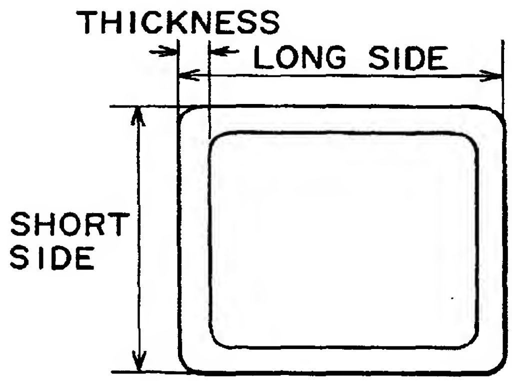


FIG.2

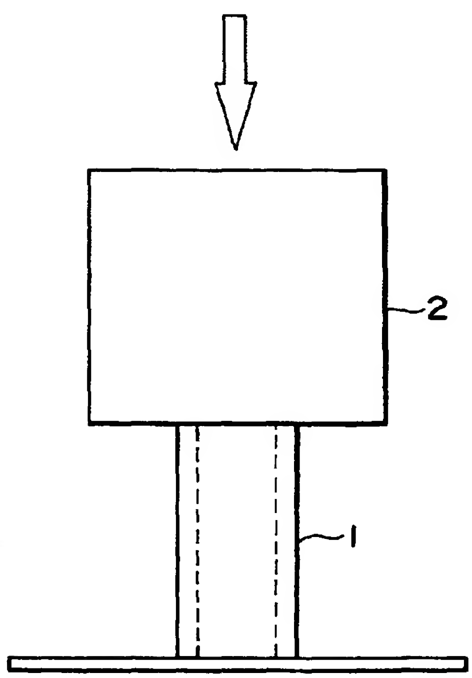
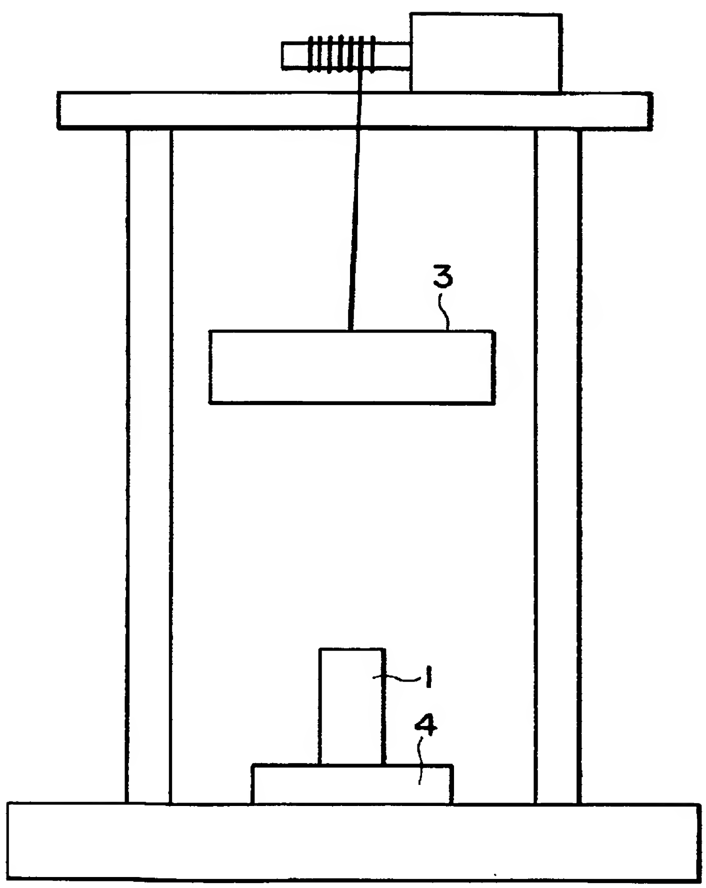


FIG. 3



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EUROPEAN SEARCH REPORT

Application Number
EP 99 12 0845

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	14 January 2000	Badcock, G

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